served for long-term storage maintaining its germinative capacity. At the same time methods for germination-tests "in vitro" had to be tested.

2. The water content of pollen of the coniferous genus *Larix,* Picea, Pinus and Pseudotsuga could be reduced to 1.5% of the fresh weight by 48 hours of freeze-drying at a temperature from $+15^0$ C to -30^0 C and a pressure of 10^{-3} Torr. Germinationtests of pollen treated in this way showed a clone-related sensitivity to freeze-drying. Pollen of some trees of the species investigated lost its germinative capacity in part or totaly whereas that of others remained unchanged. Due to the significant individual differences in reacting on the treatment applied, it is necessary to test germinative capacity "in vitro" immediately after freeze-drying. For these tests the methods of "Moist Chamber" and "Hanging Drip" proved to be specifically suited.

3. The germinative capacity of pollen conserved by freeze-drying can be maintained to a high degree for a long period if the temperature during the storage is around -10^0 C and simultaneously damping of the pollen can be prevented.

4. Field crossings with pollen conserved by freeze-drying and stored up to 4 years at -10^0 C yielded seeds and seedlings not different from the results of uncontrolled pollination.

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Heritabilities of Growth and Crown Characteristics of Arizona Cypress

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(Received / revised August 1973)

The coastal plain of the United States bordering the Gulf of Mexico does not have a native conifer suitable for Christmas tree production. Arizona cypress (Cupressus *arizonica* GREENE) has been tried with varying success. Serious problems encountered are poorly shaped trees, poor foliage color, and multiple stemmed trees. The exact seed source locations of these earlier plantings are unknown, but they are thought to be from areas in the vicinity of Gila County and Oak Creek Canyon (Sedona), Arizona.

In 1964, the Agricultural Experiment Station, Auburn University undertook the task of genetic improvement of Arizona cypress for use as Christmas trees in the southeastern United States. In the summer of that year the Station sponsored a seed collection trip to the southwestern United States and northern Mexico (POSEY and GOGGANS; 1967) to obtain seed and specimens from the species throughout its natural range. The seeds are borne in serotinous cones with bossed scales, facilitating collection in any season. Variation within and between stands was sampled. This report is based on a portion of the plantings resulting from these collections.

Materials and Methods

Areas of collection are shown in Figure 1 and described in *Table* 1. One hundred to 300 cones were collected from 12 or more trees per source. Where possible the trees were several hundred feet apart to minimize the chance of collecting from closely related trees. Each individual tree seedlot was divided into halves. One half was planted in the Auburn Forest Tree Nursery, Auburn, Alabama in March, 1965. Seedlings were lifted in the spring of 1966 and planted.

The experimental area was relatively flat, moderately-drained bottomland near Tuskegee, Alabama. The soil ranged from sandy loam to fine sandy loam. The experi-

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Gratitude is expressed to J. A. MCGUIRE and J. C. WILLIAMS, respectively Assistant ana Associate Professors, Research Data Processing, for their assistance in the statistical analyses.

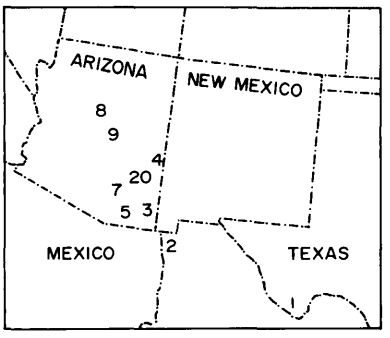

Figure 1. — Arizona cypress provenances sampled.

Table 1. — Collection areas of *Cupressus arizonica*

Source	Location	Elevation	Aspect
		feet	
1.	Big Bend National Park, Texas	6,800	North facing slope
2.	Chihauhua, Mexico	5,800	Bottom of canyon
3.	Chiricahua National Monument, Arizona	5,300	Bottom of canyon
4.	Greenlee Co. Arizona	4,900	All slopes and ridgetops
5.	Cochise Stronghold, Arizona	5,100	Northeast slope
7.	Pima Co., Arizona, Bear Canyon	5,600	Bottom of canyon
8.	Ooak Creek Canyon, Arizona	4,200	Bottom of canyon
9.	Gila County, Arizona	5,100	Ridgetops and creek bottoms
20.	Graham Co., Arizona	4,800	Northeast slope

mental planting was a split plot with 4 replications, 8 sources (whole plots), and 5 female parents (sub-plots) per source. Each family was represented by 16 seedlings in each replication though not all trees survived to time of measurement. Seed sources represented were: 1, 2, 3, 4, 5, 8, 9, and 20.

In the spring of 1966 the second half of the seed was planted in the nursery and outplanted in the spring of 1967 adjacent to the 1966 planting. The same experimental design was used. Seed sources represented were: 1, 3, 4, 5, 7, 8, 9, and 20. Neither the 1965 nor 1966 nursery planting was replicated.

Low nursery survival caused sources 7 and 2 to be omitted from the 1966 and 1967 plantings, respectively. Nursery survival of the individual family seedlots varied sharply between 1965 and 1966 necessitating the use of some different families in the two plantings. While both field plantings contained 7 common seed sources, few families were represented in both plantings. Consequently, no attempt was made to obtain estimates from a combined analysis for both plantings.

The 1966 planting was measured after the 1968 growing season and the 1967 planting after the 1969 growing season. This gave comparable measurements in both plantings at 4 years from seed or 3 years in the field. Most trees were average Christmas-tree size at the time of measurement.

Characteristics measured were total height, height at the widest point in the crown, crown diameter at the widest point, and taper. Taper was the ratio of the crown diameter at the widest point to the height from the widest point to the tip of the tree. Observational data were also collected for color, crown shape, and the single or multiple stem characteristic.

All variance components were estimated from analyses of variance for plot means except for within plot variances which were calculated on an individual tree within plot basis. Heritabilities were calculated using the following formula: $h^2 = \sigma_F^2/(\frac{1}{r}(\sigma_P^2 + \sigma_B^2 + \sigma_A^2) + \sigma_S^2 + \sigma_F^2)$. Explanation of symbols is given in *Table 2*. Because the amount of inbreeding in the base populations and the exact relationships among open-pollinated progeny were unknown, a coefficient increasing σ_F^2 to total additive genetic variance was not included in the formula. If the families were made up of half-sibs and there was no inbreeding the coefficient would have been 4. For full-sib families, inbred families, or mixtures of full-sib and half-sib families the coefficient would be smaller. Heritabilities for color were calculated using a 4-point grading system as follows: 4 = blue-gray, 3 = dark green, 2 = medium green, and 1 = light green. Blue-gray was considered the most desirable and light green the least desirable color.

Results and Discussion

Means of the measured characteristics, percent multiple stems, and color are given in *Table 3*. SPEARMAN'S rank correlations of source performances between the two plantings were calculated for each characteristic and were nonsignificant at the .05 level of testing except for crown diameter. This indicates the existence of genotype × environment interaction at the source level of genetic differences. In general, trees from sources with a large total height had large crown diameters and small tapers, and trees from sources with shorter heights had smaller crown diameters and larger tapers.

Estimates of heritability for the measured characteristics and color are presented in *Table 4*. The estimates are not completely consistant between the two planting years. This may be caused by the use of different families in the two

Table 2. — Typical ANOVA showing expected mean squares and in particular the observed mean squares for height of the 1966 planting.

Sources of variation	d.f.	M.S.	Expected mean Square*
Replicates	3	1.18	
Sources	7	12.32	$\sigma_P^2 + \sigma_B^2 + f\sigma_A^2 + r\sigma_F^2 + rf\sigma_S^2$
Error a	21	.37	$\sigma_P^2 + \sigma_B^2 + f\sigma_A^2$
Families/sources	32	1.43	$\sigma_P^2 + \sigma_B^2 + r\sigma_F^2$
Error b	96	.28	$\sigma_P^2 + \sigma_B^2$
Plants/plots	1932	2.23	σ_P^2

* σ_S^2 = Variance component for sources

σ_A^2 = Variance component for whole plot errors

σ_F^2 = Variance component for families in sources

σ_B^2 = Variance component for plots within replicates

σ_P^2 = Average variance for plants within plots = σ_W^2/n

σ_W^2 = Variance among plants within plots

n = Harmonic mean of the number plants per plot, 12.2 and 12.5 for 1966 and 1967 plantings, respectively

r = Number of replicates = 4

s = Number of sources = 8

f = Number of families per source = 5

Table 3. — Provenance means.

	Total height		Crown diameter at the widest point		Height at the widest point		Taper		Trees with Multiple stems		Color	
Planting date	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967
Source	feet		feet		feet				percent			
1	7.5	6.3	2.2	2.0	2.2	2.9	.43	.67	51	63	1.7	1.8
2	9.5		2.8		2.7		.42		61		2.1	
3	8.2	7.2	2.5	2.4	2.3	3.0	.46	.59	47	32	1.9	2.0
4	8.3	7.1	2.5	2.3	2.5	2.9	.46	.60	46	46	1.9	1.9
5	8.7	7.0	2.5	2.2	2.7	3.2	.43	.61	37	33	2.1	2.1
7		5.8		2.2		2.8		.87		52		1.3
8	7.1	6.4	2.1	2.1	2.6	3.0	.50	.66	56	61	2.2	1.6
9	7.4	5.9	2.5	2.1	2.5	2.8	.52	.75	82	72	2.1	1.8
20	8.2	6.6	2.4	2.2	2.5	2.8	.46	.65	40	50	1.9	2.0
Mean	8.2	6.6	2.4	2.2	2.5	2.9	.46	.67	52	50	2.0	1.9

Table 4. — Estimates of heritabilities

Characteristic	Plantation 1966	1967
Total Height	.32	.50
Height at Widest Point	.62	.29
Crown Diameter	.52	.84
Taper	.50	.61
Color	.66	.54

plantings, or by genotype × environment interactions which may also exist at the family level as well as the source level of genetic differentiation. Also, there was no replication of the nursery plantings; therefore some of the family variation may have been caused by environmental variation in the nursery.

The contributions of variance components of sources, families, and plants to the total of the three components are given in *Table 5*. In only one instance, the 1966 total height analysis, was the variance associated with sources relatively large. This along with the high family heritabilities indicates selection of families would be the fastest method of varietal improvement. Care should be taken, however, to avoid selection from sources with a high percentage of multiple stemmed trees and poor color. Further selection of plants within families may also be profitable, but the amount of environmental variation in the plant component is unknown making the expected gain by this method an uncertainty.

Key words: Heritability, provenance, Arizona cypress, Christmas trees.

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Table 5. — Variance components expressed as percent of total variance associated with sources, families, and plants.

Characteristic	Total Height		Crown diameter at the widest point		Height at the widest point		Taper		Color	
Planting	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967
Sources	53	29	27	0	27	0	12	21	4	22
Families	29	48	43	64	43	64	30	51	52	45
Plants/family plots	18	23	30	36	30	36	58	28	44	33